

From Knowledge to Meaning: User-centered Product Architecture Framework Comparison between OMuKE and SAPAD

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Abstract: This paper analyzes the methods of Object-Mediated User Knowledge Elicitation (OMuKE) and Semiotic Approach to Product Architecture Design (SAPAD). OMuKE clearly shows the relationship from behavior to object and from the relationship between task (behavior) and the use, user knowledge is analyzed. SAPAD analyzes the mapping between behavior, signification and product, and explore product architecture from the perspective of signification. Comparing the two research frameworks, it proposes that object system is similar, but the signification system is totally difference.

Introduction

In the social context of globalization and tendency of multicultural convergence, the homogenization of product design is serious. Companies on the one hand instinctively reduce costs, shorten product development cycles, on the other hand provide products which meet the heterogeneous needs of users. Construction Products as a method enhance the competitiveness of enterprises, which gained widespread attention and study in recent years.

Ulrich and Eppinger (1995) define product architecture (PA) as: product construction is a form of allocation. It is the scheme by which the function of a product is allocated to physical components, aiming to define the basic physical building components. Ulrich (1995) articulated five potential application areas of product architecture: 1) product change; 2) product variety; 3) component standardization; 4) product performance; 5) product development management.

Rosen (1996) and Sosa (2000) developed it as a form based method. Through modular systems and integrative system, the research on coupling of product architecture is conducted to couple product architecture and organization structure. Zamirowski and Otto (1999), Stone, Wood and Crawford (2000) developed it as a function based method, which transformed function structure of product into a visible PA, and realized its function through components or subassemblies. The concept of product family is introduced into PA that based on product function. PA was regarded as the basis and methodology of product family strategy (Erens and Verhulst, 1997; Dahmus, Gonzales, Zugasti and Otto, 2001; Martin and Ishii, 2002; Kariman and Herrmann, 2009). Other scholars studied it from the perspective of product life cycle, design, assembly and maintenance disassembly belonged to PA research (Rosen, 1996; Wyatt, Wynn and Clarkson, 2009; Dagman and Söderberg, 2012). Further, PA was regarded as the general mechanism of design integration method (Antonsson and Cagan, 2001; Chakrabarti, (2002).

In recent years, the uncertainty of PA is increasingly concerned. Moullec and Jankovic (2012) proposed applying Bayesian nets method to PA. Gedday and Maraghy (2013) discussed the granularity standard in modular product architecture, applied cladistics method of DSM (design structure matrix) to reconstruction, and proposed hierarchical clustering. Ko (2013) used Boolean

matrix, a kind of efficient and flexible fuzzy design structure matrix, to increase the diversity of products and reduce the amount of components iteration.

The research is widespread and far-reaching, but it conducts PA focused on the dimension of object. From the perspective of human, PA is first used to construct product based on consumer requirement by Yu, Zugasti and Otto (1999). Sakol and Sato (2002) proposed “Object mediated User Knowledge Elicitation” (OMUKE), which focuses on the hierarchical task analysis. Hu and Sato (2012) put forward a new framework “Semiotics Approach of Product Architecture Design” to analyze the mapping between behavior, signification and product, and explore product architecture from the perspective of signification.

On OMUKE And Its Case Study

OMUKE (Object-mediated user knowledge elicitation) is raised by Sakol and Sato. OMUKE makes a process to explore the relation between use process and product, and stimulate user knowledge with objects to help them to describe experience in order to find the chance of design.

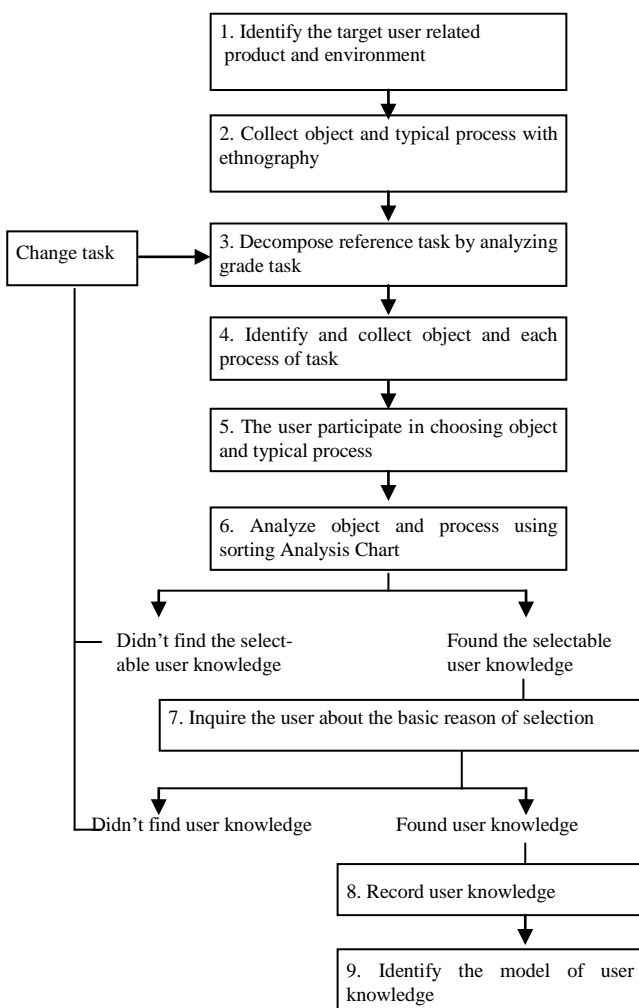


Fig.1 Process of OMUKE

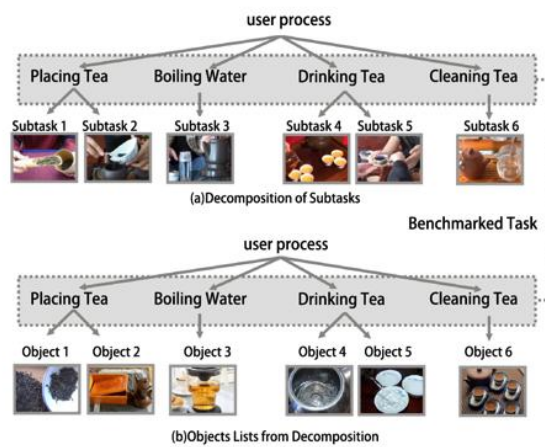


Fig.2 Decomposition of User Process into Subtasks and Objects

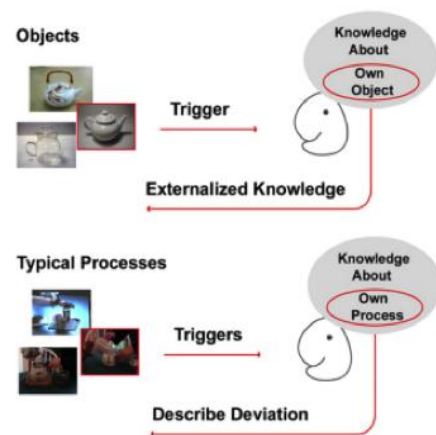


Fig.3 Triggering Mechanisms

The process of OMUKE obtaining user knowledge includes: the choice of target user and product, collection of data, decomposition the task, identification materials, user participation, analysis of target and the process and searching for the model of user knowledge. Concrete process is shown as Fig.1. (1) Location of research’s aim and range of research. Product maybe existing product or the combination of product related to task of field research. (2) Research collected data after determining the scale of project. The collected data includes target, environment and use process. (3) The task is decomposed into subtasks by level. (4) Researcher must identify the process and target in each subtask. The picture of target and the video of process regard as database for user. (5) The user

participates in choosing target and explains the process of each subtask. (6) We consider the sorting of targets, after collecting the result of user's choice. If the choice doesn't match the user knowledge, researchers must change the structure of survey. (7) Researchers explore the user's potential knowledge from user's aim and process, and ask for the user to explain the reasonableness of choice. If the user knowledge may be not obtained, researchers check the structure of survey (return to 3). It may be difficult for user to modify the product so that user knowledge is difficult to obtain. According to the experience of mobile phone, the product is so complex that user doesn't modify the accessories to match their behavior (develop a new method to package phone in travelling. (8) Record the temporary data if the user knowledge is found. (9) Confirm user knowledge and find the user mode by pattern recognition.

Make Indian tea in office as example. Inquiry Decomposition: User experience and knowledge can be analyzed by looking into the structure of the user process and the object used. The users behavior can be represented as a hierarchical structure produced by Hierarchical Task Analysis.

Instead of describing the user process in details, we identify benchmarked tasks based on user observations. The benchmark tasks were decomposed into small subtasks (Fig.2a). In the same way, the objects used in each benchmark task were listed (Fig.2b). These benchmarked tasks will be used as a structure for queries both objects and processes.

Triggering Mechanisms: The photographic images of artifacts are used as a triggering mechanism for externalizing user knowledge. The second triggering mechanism is a typical process - well understood processes among users. Users were asked to describe what parts of the process presented in the video clips were alike or different from their processes. The process helps users describe the actual experience through a given example. Objects and processes used in this method do not need to match exactly with what users have or do. They provide referential points for users to explain their own objects and processes. (Fig.3)

Patterns of User Knowledge are design documents. They are a combination of a solution from users and designers. The patterns represent user knowledge, user needs, context of use, and possible solutions. From the result of OMUKE method, user knowledge was developed before the user needs were identified. The user knowledge form can be described as the object, process of use and the rationale behind these. The context of use includes the user experience and the environment of products. The product configuration is a possible solution that will be integrated into a new product while the user process represents the scenario of use that expects to have.

To accommodate the existing product and user process, the pattern of knowledge should be considered as a module or partial integration. Some user knowledge has the potential to create an entirely new product.

Semiotics Approach of Product Architecture Design

Generally, human-machine interaction includes two dimensions: subjective dimension (user's behavior) and objective dimension (feedback of product). The author regards the HCI system as a semiotic system in which behavior act as "Media", product act as "Object", signification act as "Interpretation", referring to the Peirce's trichotomy. Therefore, acting as "Interpretation" for motivation and demands, signification becomes the third dimension. Referring to the Peirce's research continually the conception of hierarchy was introduced into signification-behavior-object. Referring to the theory of Product Architecture, the dimension of object can be divided into four levels: assembly, object, unit and component. Component includes the activity of all products that was applied for completing task in the process. Every product can be divided into some parts based on different aims and every unit is composed of many components. Referring to the behavior science, the dimension of behavior can be divided into four levels: activity, process, action and operation.

Finally, In the dimension of signification, compared the Morris' semiotic triangle theory (1938), Nauta's semiotic cube theory, Stamper's semiotic ladder theory and Cordeiro and Filipe's semiotic pentagram theory, the author finally define the level of human computer/product interaction which is base on Stamper's semiotic ladder theory. It includes six levels as follow: 1) Physical level of signification is about "what" in physical attribute, which is related to function, such as material, signals, traces and physical distinctions; 2) Syntactic level of signification is about "how" to connect with each other between the function modules; 3) Empiric level of signification is about "how" to connect the subject with object between the interaction and it relates to construction of logic, which focus on the operation and control of object, the users' experience such as mode, way, noise, redundancy and efficiency etc.; 4) Semantic level of signification is about "why" to interact between individual and object, which relate to emotional experience and focus on emotion, character and persuasiveness of object, such as theme, expression, and intention; 5) Pragmatic level of signification is about "how" to communicate in interactions, which focuses on sub-culture and group identity; 6) Social level of signification is about social attributes in the interaction, which focuses on value and ideology and relates to beliefs, expectation, commitment, contract, law and cultural convention. The three dimensions of SAPD framework are shown in Fig.4.

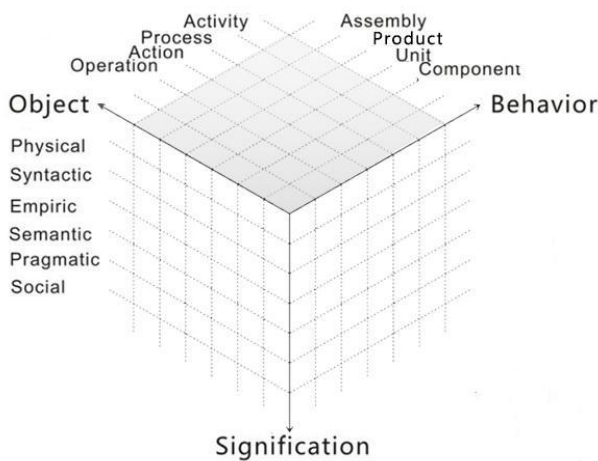


Fig.4 TheThree Dimensions of SAPAD Framework

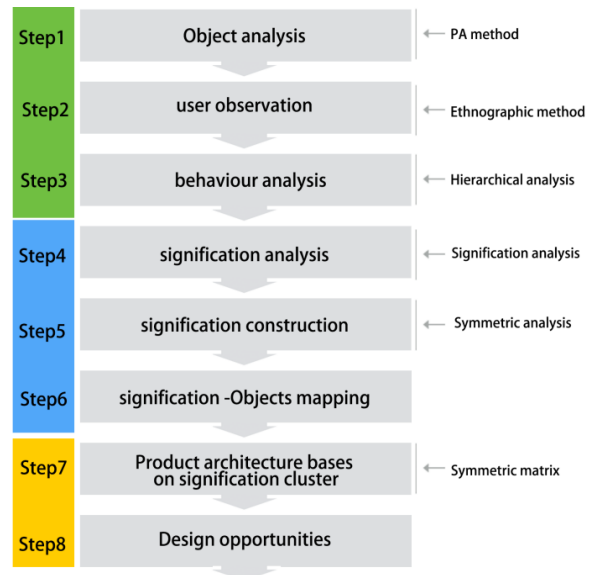


Fig. 5 The Research Flow of SAPAD

The Research Flow of SAPAD

First part: Behavior observation and analysis. It includes 3 steps: 1) Object analysis. Using PA method to analyze objects (product or service system) and create product schematic, cluster schematic elements, establishing a rough geometric layout, determining basic and occasional interaction (Ulrich, 1995). 2) Users observation. Applying ethnographic method mainly to record the relation of user behavior, environment and objects by videoing, photographing, noting and other forms. 3) Behavior analysis. Applying the Analytic Hierarchy Process to make behavior hierarchy and layer behavior according to activities, processes, action and operation, outlining the structure of the user's behavior and related items clearly.

Second part: Signification analysis and construction. It includes 2 steps: 4) Excavating the undermeaning of the user's behavior by analyzing physical level, syntactic level, experience level, semantic level, pragmatic level and social level. 5) Signification construction. Making sure of the accuracy and availability of signification through interviewing user again, at the same time, reconstructing signification cluster, insight into the crucial meaning of behavior and core values of the user and possible design directions by matrix hierarchical clustering.

Third part: Product construction and design. It includes 3 steps: 6) Signification-Objects mapping. Combining with 4), 3), 2) to determine the mapping among and between signification cluster (four levels) and things, defining the key objects of signification. 7) Product architecture bases on signification cluster. Assigning the number to the relationship of object signification base on {0, 3} Brin logic and outputting new units, new products or new groups by symmetric matrix. 8) Design opportunities. Defining new function and new structures of product, legible design opportunities and concrete paths for innovation base on the new combination based on component, unit, object and assembly levels. The research flow of SAPAD is shown in Fig.5.

Case Study of Oolong Tea Making

Observation and User Behaviour Analysis: Observation study was conducted to capture the activities in Oolong tea making and tasting processes. The activity of making Oolong tea at home could be divided into six sub-processes as shown in Fig.6: 1) preparing water, 2) preparing tea equipages, 3) preparing tea, 4) making tea, 5) tasting tea, 6) cleaning.



Fig.6 Six processes of Oolong Tea Making Activity

Action-Object Analysis: Oolong tea making is a very complicated activity, which involves eighteen objects. The relationships between actions, objects and significations were identified. Next, the researchers analyzed potential significations in each action at physical level, syntactic level, empiric level, semantics level, pragmatic level and social level. After an interview with the participants to avoid misunderstanding of their behaviors, eleven signification factors represented as Si in the table were identified in this activity: 1) cleaning; 2) economy; 3) recreation; 4) experience; 5) convenience; 6) carefulness; 7) at-will; 8) self-expression; 9) knowledge; 10) etiquette; 11) elegance.

	economy	convenience	at-will	recreation	elegance	experience	knowledge	self-expression	etiquette	cleaning	carefulness
economy	1										
convenience		1				1					
at-will			1	1							
recreation			1	1	1						
elegance				1	1		1	1			
experience	1					1	1	1	1		
knowledge					1	1	1	1	1		
self-expression					1	1	1	1	1	1	
etiquette						1	1	1	1	1	
cleaning								1	1	1	1
carefulness											1

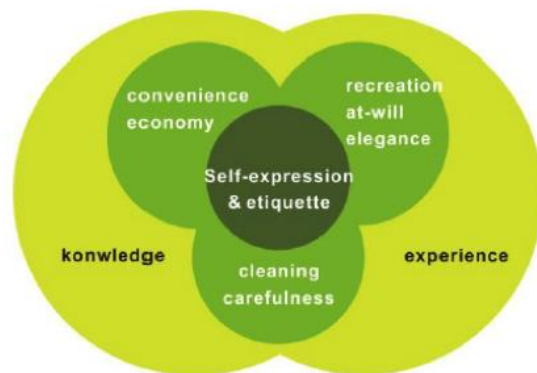


Fig.7 Signification Architecture & Signification Modules

Signification Analysis: Based on the cluster analysis, five signification modules were formed in three levels: 1) in the pragmatic and social level, etiquette and self-expression were core signification factors; 2) in semantics level, the significance module of elegance, relaxation and at-will, the significance module of carefulness and cleaning, and the significance module of convenience and

economy represented the personality and characteristic of the user; 3) in empiric level, experience and knowledge were the basis of this activity.(Fig. 7)

Design Opportunities: Finally, eight modules were confirmed as pre-cleaning module, heating module, auxiliary module, tea set storing module, cleaning module, tea making module, tea leaves storing module and self-expression module. The relationships among eighteen objects in these modules were shown in Fig.8 (left). It was obvious that tea making module, tea leaves storing module, self-expression module and tea set storing module were very close each other, and self-expression module and tea set storing module were almost identical. From the signification analysis in Figure 8, the key of this activity is not to quench thirst or care health for himself, but to express etiquette and himself to the visitors, which is just a desired and unmet need. So a potential system boundary for a new product appeared clearly. There should be an integrated tea table system that provides multiple functions such as storing, tea-making and representing the host, as shown in Fig.8 (right).



Fig.8 Design Opportunity

In the case study of Oolong tea making activity at home, rich significations appeared in user activity, and were projected into twenty-one actions and eighteen objects correspondingly. Four levels of significances were discussed and emphasized in this case study. The core and crucial meanings were etiquette and self-expression in the pragmatic level and social level. The different significances in the semantics level reflected the personality and diversity of the users, such as elegance, relaxation and at-will, carefulness and cleaning, convenience and economy. And there were common experience and knowledge of users groups in the empiric level. More important, different significations kept closely connection to different objects and units, which seemed to find a new possibility for product architecture.

Conclusion

Product Architecture theory is a manufacture-oriented product development, whose essence is product function. OMUKE framework pushed Product Architecture theory into capturing user knowledge. As for the concept “User knowledge” can cover the empiric level, semantic level, pragmatic level and social level of semiotics ladder. OMUKE distinguish the user knowledge between person and public, the former corresponds to the empiric level and semantic level of semiotics ladder, the latter corresponds to the pragmatic level and social level of semiotics ladder. Even though there is the possible of covering the semiotics ladder exist in OMUKE, but concerning the case “India tea”, OMUKE captures the user knowledge triggering by the target object and typical process, mainly in empiric level, slightly involved in semantic level (Table1, Fig. 9). It is more important that the method can’t be chosen to be a popular science paradigm under the specific situation. Without the specific situation and usage, the value and signification of user knowledge can’t be confirmed, which captured by OMUKE.

Pattern Name	Fast Boiling Water
User Knowledge	Microwave oven, warm water and mug for the boiling process make fast boiling water. <object><process of use><rationale>
User Needs	Time of boiling water takes around 10 minutes. Many users are impatient to wait during this process.
Context of Use	The user makes tea at school where there is a dispenser for hot water and a microwave oven. User always wants a fast boiling process during this stage.

Table 1 Pattern of User Knowledge Format

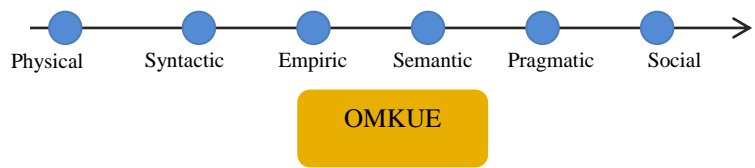


Fig.9 the Signification Level Involved in OMKUE

The behavior of Oolong tea making has strong regional culture characteristic itself, therefore it is reasonable to find that the rich signification in Pragmatic level and Social level. Sakol and Sato (2002) have researched on the case “India tea”. As for the physical level and syntactic level, there is no big difference compared with case 1, but concerning the core signification, convenient and quick is the core signification of India tea making in office. Moreover, Self-expression and manner is the core signification of making modern tea in China. Object system is similar, but the signification system is totally difference. By comparison, SAPAD adds signification analysis and signification construction in research flow, so that it is able to dig the deeper signification in user Pragmatic level and Social level. (Fig.10)

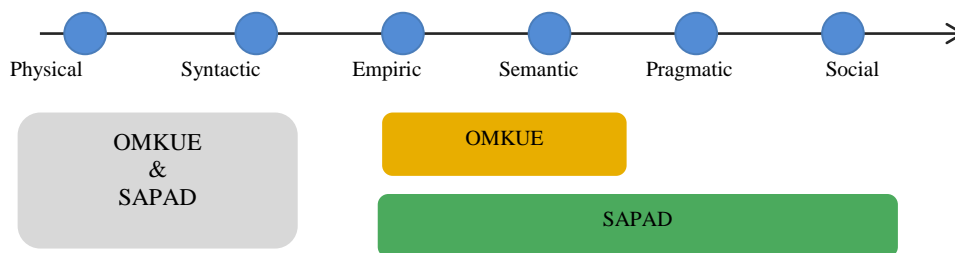


Fig.10 the signification level involved in OMKUE&SAPAD

Undoubtedly, the SAPAD framework makes user-centered Product Architecture theory more completely and comprehensively. The introduction of semiotics ladder makes the signification that is on the design axis between person and object relation more clear and explicit: the physical level means the object itself; the syntactic level means the relationship between object and object; the empiric level means the relationship between object and person; the semantic level means the person himself; the pragmatic level means the relationship between person and subculture groups (or audience, segmentation); the social level means the relationship between person and social (or the public) . Using semiotic ladder, SAPAD framework makes user knowledge in a more comprehensive range and more legible level. We can say user knowledge is included in user signification. (Fig.11)

Signification excavating is not the ultimate goal. In terms of the discovery of functional



Fig.11 the Relationship between User Knowledge and User Signification

signification of the physical level and syntactic level, or individual experience and emotion excavated from the experience level and semantic level, or socially cultural signification excavating from pragmatic and social level, the ultimate goal is to translate it into useful design knowledge that can be converted into products by designer.

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